2020

Definitions of Water Quality: A Survey of Lake-Users of Water Quality-Compromised Lakes

Ashley Votruba

Jessica R. Corman

water

MDPI

Article

Definitions of Water Quality: A Survey of Lake-Users of Water Quality-Compromised Lakes

Ashley M. Votruba [1,*] and **Jessica R. Corman** [2]

[1] Department of Psychology, University of Nebraska-Lincoln, Lincoln, NE 68588, USA
[2] School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE 68588, USA; jcorman3@unl.edu
* Correspondence: ashley.votruba@unl.edu

Received: 30 April 2020; Accepted: 18 July 2020; Published: 25 July 2020

check for updates

Abstract: Understanding and defining water quality is an important precursor for influencing pro-environmental behavior and accurately assessing potential outcomes of human–lake interactions. This study surveyed 82 lake-users in Nebraska regarding their definitions of water quality and the importance of various water quality features to determine if lake-users' definitions align with complex and multi-faceted governmental and scientific definitions. Survey sites included two recreational reservoirs (e.g., boating and fishing), Holmes Lake (urban watershed) and Branched Oak Lake (agricultural watershed). The biological and chemical parameters are similar between the lakes and both lakes were listed as "impaired" on the Section 303(d) (United States Environmental Protection Agency, Washington, DC, USA) list of impaired waters of the US at the time of the surveys. The results of our survey suggest that the overwhelming majority of lake-users' self-generated definitions of water quality did not include more than one feature of water quality found in the relevant policy and regulatory definitions and they focused primarily on water clarity. Further, when provided a list of specific water quality features, the participants rated all provided features of water quality as highly important. This suggests that the failure to include those features in a self-generated definition is not the consequence of perceiving that feature as low importance.

Keywords: water quality; environmental perceptions; survey research; lake recreation; water clarity; definitions

1. Introduction

Across the US, over a third of lakes are facing water quality problems [1]. However, what does it mean to have good water quality? How do the public, government, and stakeholders conceptualize water quality? What are the essential characteristics or features of water quality?

For lakes, "good" water quality can be defined by many factors, including visual appearance, ability to recreate, or habitability for certain species. As described by the World Health Organization, "In view of the complexity of factors determining water quality, and the large choice of variables used to describe the status of water bodies in quantitative terms, it is difficult to provide a simple definition of water quality" [2]. Water quality can represent diverse critical ecosystem services, such as clean drinking water [3], food security through fisheries [4], and mental well-being [5].

Federal legislation provides some insight into how the government perceives water quality and the pertinent issues surrounding water quality. In 1972, the federal government passed the Clean Water Act (officially called the Federal Water Pollution Control Act, Congress, Washington, DC, USA) with the ambitious and broad objective "to restore and maintain the chemical, physical, and biological integrity of the Nation's water" (33 U.S.C. § 1251(a) (2018), Congress, Washington, DC, USA). The Act focused on water "pollution" defined similarly as "the man-made or man-induced alteration of the chemical, physical, biological, or radiological integrity of water" (33 U.S.C. § 1362 (19) (2018), Congress, Washington, DC, USA). The broad overarching goal was supplemented with a number of secondary goals that guide federal (through the Environmental Protection Agency, EPA, Washington, DC, USA) and state implementation (33 U.S.C. § 1251(a) (2018), Congress, Washington, DC, USA). These goals include eliminating the discharge of pollutants into navigable waters and providing for the protection of fish and wildlife as well as recreation in and on the water (33 U.S.C. § 1251(a) (2018), Congress, Washington, DC, USA).

Congress identified three components of water quality standards in the Act (EPA, Washington, DC, USA): (1) designated uses such as drinking water, protecting wildlife, and promoting water recreation; (2) water quality criteria defined as measured characteristics necessary to promote the designated uses; and (3) antidegradation policies that states are required to adopt [6]. The Act sets minimum water quality standards, but recognizes that states face a variety of environmental conditions and concerns. Thus, it allows states to adopt unique water quality standards above the set minimum requirements that align with their needs and philosophies. Thus, states—specifically their environmental agencies—play an important role in defining their own water quality standards and establishing specific water quality regulations and policies.

Given this flexibility, it is also important to examine state legislation and regulation to understand the government's conceptualization of water quality. Our study takes place in Nebraska, a region of the country with known water quality impairments due to nutrient pollution, as assessed by the EPA [1]. The state of Nebraska defines water quality as "the biological, chemical, physical, and radiological integrity of a body of water (Nebraska Department of Environment and Energy, Tile 117, Ch. 1, Lincoln, NE, USA)." The definitions subsection of this legislation further detail what is meant by each of those properties (Figure 1). Reviewing this legislation suggests that policymakers (at various levels of government) adhere to a conceptualization of water quality that is complex, broad, and encompasses multiple components of water quality.

Water quality definitions by the Nebraska Department of Environment and Energy:

071.01 "Biological Integrity" means the plant, animal, and bacteriological species composition of a body of water.

071.02 "Chemical Integrity" means the chemical properties of the water, sediments, or biological organisms (e.g., concentrations in fish tissue) of a body of water.

071.03 "Physical Integrity" means the physical properties (e.g., temperature, turbidity, sedimentation) of a body of water.

071.04 "Radiological Integrity" means the radioactive properties of the water, sediments, or biological organisms (e.g., concentrations in fish tissue) of a body of water.

Figure 1. Water quality definitions by the Nebraska Department of Environment and Energy.

However, does the public also have a complex, multi-faceted definition of water quality that encompasses a variety of features like the definitions seen in governmental policies and regulations? Most environmental problems are extremely complex, including issues associated with water quality. Yet, we do not fully understand how the general public understands complex environmental systems or the implication of that understanding for the public's ability to comprehensively define the concepts associated with that environmental system. It could be that non-experts may fail to adopt a complex, multi-faceted definition of water quality. Consequently, this may impair some lake-users' awareness of the complex and nuanced issues surrounding water quality. Thus, better understanding the general public's definitions of important environmental terms like water quality is worthy of increased scientific study.

Relatedly, it is generally recognized that knowledge is a precursor to pro-environmental behavior [7–10]. Although knowledge of environmental issues is not the sole factor predicting pro-environmental behavior, environmental models generally recognize that it is a necessary component [9,11,12]. Further, knowledge-based interventions (often in the form of public information campaigns) are a popular way of promoting pro-environmental behaviors [8,13], however, the effectiveness of these intervention programs shows mixed results. Thus, it may be useful to consider alternative factors that impact communication between the public and policymakers and scientists such as how the public defines complex environmental terms like water quality.

Research focusing specifically on the issue of water quality has primarily examined public perceptions of whether water quality is “good” or “bad” (typically along a continuum) at a specific location. Broadly, these perceptions are influenced by both features of the lake and features of the individual. As reviewed in Canter et al. [14], important factors influencing perceptions of water quality include pollution visibility, personal use of water, dwelling proximity to a polluted lake, trust in government, and demographic factors including education level and age. More recent work finds evidence that a person’s mood or the weather [15] and familiarity with water quality issues in their region [16] can also influence perceptions. Integrated socio-environmental models have taken this work a step further and examined the association between public perceptions of water quality and objective measures of water quality, generally focusing on how objective measures of water quality influence public perceptions. Across multiple studies, parameters like water transparency and phosphorus or chlorophyll *a* concentrations are often associated with perceptions of water quality [17–21]. However, the relationship between these lake water parameters and public perceptions of water quality is often weaker at lower water quality levels [17,20].

Public perceptions of water quality are also influenced by the public’s personal experiences with bodies of water and the comparisons those experiences promote. Larger scale comparisons of water quality perception and lake water parameters suggest that perceptions are based on local thresholds: what is considered low water clarity or “bad” water quality in a region with many oligotrophic or clearer-water lakes may be perceived as having high water clarity or “good” water quality in a region with more eutrophic or greener and more productive lakes. For instance, a 1987–1988 survey of lake-users in Vermont and Minnesota examined perceptions of water clarity [22]. The results indicated that lake-users in Vermont (where, proportionally, more lakes were oligotrophic) described lakes with Secchi depths of 3–4 m as having “definite algal greenness, yellowness, or brownness apparent”, while lake-users in Minnesota (where, proportionally, more lakes were eutrophic) described lakes with an equivalent Secchi depth as “crystal clear water” or “not quite crystal clear, a little visible algae” [22]. Authors of the Vermont and Minnesota study did not offer a reason why the responses might be regionally specific [21]. In a more recent study, based on the 2007 and 2012 US National Lakes Assessments (NLA, EPA, Washington, DC, USA), similar results were found. Trained field crews in the “Plains and xeric region” (a consolidated eco-region classification with a higher proportion of eutrophic lakes) consistently gave higher aesthetic appeal ratings than trained field crews in the “Mountains and upper Midwest region” (a consolidated eco-region classification with a higher proportion of oligotrophic lakes) to lakes with similar Secchi depth measurements [21]. Authors of the NLA study suggest that other factors besides water clarity may contribute to aesthetic appeal, but go on to point out that human expectations of the quality of benefits from a lake likely scale to the “prevailing condition of lakes in the region” [21].

Although understanding public perceptions of whether water quality is “good” at a particular site is important, we argue that the implications of those perceptions would be better understood if we also knew how those perceptions are conceptualized. When individuals are assessing water quality, what parameters influence those perceptions? This drives our primary research questions: How do non-expert individuals define water quality? What are the essential characteristics or features of water quality for those same individuals? These are important questions because effective management of lakes inherently involves the general public [14,16]. Integrated socio-environmental system models draw a strong connection between human behavior and the biophysical components of aquatic ecosystems [23,24]. Research that seeks to (1) better understand how non-expert individuals' conceptualize and define water quality and (2) relate those definitions to actual water quality has the potential to fill a gap in our understanding of the human component of socio-environmental system models. This understanding could inform policy and public actions that then influences key individual behaviors. Ultimately, understanding public conceptualizations and definitions of water quality could be an important step in recognizing ambiguities or differing interpretations of water quality between non-experts and experts, resolving those differences, and leading to better engagement of the public in environmental management and planning [25].

1.1. Present Study

Being able to conceptualize and define a complex environmental issue like water quality is likely an important precursor for an individual to accurately assess the water quality of a specific lake and modify relevant behaviors to promote better quality water. For example, water clarity is a commonly referenced attribute when a person is asked about water quality [20]. However, this attribute does not necessarily integrate all components of water quality and may even incorrectly cue positive or negative perceptions of water quality. For instance, the recovery of lakes in the Adirondack mountain region of New York, USA, from the negative effects of acid rain is coincident with decreases in water clarity, either due to increased dissolved organic matter influx or increases in biological productivity [26,27]. Counterintuitively, in this case, decreases in water clarity actually indicated better water quality. Hence, in this example, if water quality decisions were made solely on the basis of water clarity, this would overlook the positive changes in the lake water quality coincident with reductions in acid rain: mainly, decreases in toxic aluminum concentrations within those surface waters [28].

The majority of the literature on public perceptions of water quality has focused on whether individuals characterize the water quality of a specific site along the dimension of "good" or "bad." Although informative, it does not elucidate the features and characteristics that the public uses to make those assessments. In other words, it provides no insight into how the public defines water quality. Since policymakers and lake-stakeholders often emphasize the importance of defining water quality, we argue that it is also crucial to understand: (1) how the public defines water quality including which features are most salient and (2) if those definitions align with those of policymakers and stakeholders.

In this study, we surveyed lake-users regarding their definitions of water quality and asked them to rate the importance of various water quality features that align with those emphasized in the multi-faceted policy, regulation, and scientific definitions. Participants provided their definitions in an open-ended response format, allowing us to explore the complexity of self-generated definitions from the public. We also asked participants to provide their perceptions of water quality and determine how this perception varied with familiarity with the water body, general knowledge about water quality issues, and education. We hypothesize that lake-users' definitions of water quality will lack the complexity and nuance of definitions generated by policymakers and stakeholders. Based on the findings from the reviewed literature, we suggest two alternative hypotheses about the perception of water quality of lake-users in areas with poor water quality: (1) perceptions of water quality will be unrelated to lake water parameters, as lake water quality is below the threshold at which the public strongly perceives differences or (2) perceptions of water quality will be related to lake water parameters, as lake-users are more sensitive to differences in lakes they experience locally.

1.2. Lake Issues in the Plains

Over three-fourths of lakes in the US temperate plains region are classified as either hyper-eutrophic or eutrophic according to the 2012 National Lakes Assessment (EPA, Washington, DC, USA) [1]. Lakes in the U.S. temperate plains are mostly in "working" landscapes, which are watersheds containing intensively cropped monocultures, concentrated feedlots, and grazed rangelands and, hence, can receive nutrient-rich runoff from fertilizer use or erosion in these regions. Water quality issues related to this nutrient pollution, ranging from nitrate contamination to harmful cyanobacterial blooms, can negatively impact the use of these lakes for both recreation and livestock or wildlife drinking or habitat use [29]. Lakes in urban and peri-urban nutrient-enriched landscapes may suffer unique and potentially exacerbated water quality challenges: increased prevalence of invasive species invasion [30,31], industrial point or non-point source pollutants [32,33], and regulation/modification of flow [34]. Yet, these lakes offer close and often affordable recreational opportunities for city dwellers. Outdoor areas near urban and peri-urban areas provide important health and well-being environments [29]. Hence, individual decision-making about how and when to safely recreate near or in these lakes is contingent upon their ability to assess the water quality.

2. Materials and Methods

2.1. Field Site Description

Holmes Lake is a 0.45 km^2 reservoir located within the city limits of Lincoln, NE, while Branched Oak Lake is a 7 km^2 reservoir located 40 km outside of Lincoln, NE. Both lakes are immediately surrounded by recreational areas. The watershed of Holmes Lake is primarily composed of suburban neighborhoods while the watershed of Branched Oak Lake is primarily agriculture. Holmes Lake is a city park, managed by the City of Lincoln, while Branched Oak Lake is a state park, managed by Nebraska Game and Parks. Both lakes allow for boating, fishing, picnicking, and walking on trails and are both identified as "Impaired" for aquatic life by the Nebraska Department of Energy and Environment pursuant to Section 303(d) of the federal Clean Water Act [35]. This impaired designation was based on chlorophyll *a*, total nitrogen, and total phosphorus concentrations. Furthermore, Holmes Lake also has a fish consumption advisory based on mercury concentrations [36]. Information related to different indices of water quality in both lakes for the years 2014–2019 was obtained from the Nebraska Department of Environment and Energy and are reported herein.

2.2. Participants

We surveyed 82 participants who were located at one of two recreational lakes in Eastern Nebraska (Holmes Lake: n = 55; Branched Oak Lake: n = 26). Participants were randomly approached by trained research assistants instructed to invite everyone who walked by their posted spot to complete the survey. There were enough surveys available for all who wanted to participate, however many people declined to participate in the survey (response rate data were not collected). The sample size was primarily limited by the number of times the research team was available to go to each site for data collection. Holmes Lake generally had more lake-users because it is in an urban environment, resulting in a greater number of survey participants. The participants were not offered any form of compensation for completing the study.

2.3. Procedures

Data collection involved in-person surveys of individuals engaged in recreation at two popular lakes in Eastern Nebraska: Holmes Lake and Branched Oak Lake. The research team chose these sites because they have a high volume of recreational use and have a close proximity to the University of Nebraska-Lincoln. Data collection occurred in May and June of 2019 during peak use times including evenings and weekends. The research assistants administering the survey consisted of personnel from the Methodology and Evolution Research Core (MERC) at the University of Nebraska-Lincoln and undergraduate and graduate research assistants from the Culture, Conflict, and Law Lab (Lincoln, NE). Everyone who administered the survey was certified in ethics and compliance training through the Collaborative Institutional Training Initiative (CITI) Program and received appropriate training on the survey protocol.

Research assistants with copies of the survey approached potential research participants inviting them to participate in the study. If they agreed to participate, the participants provided verbal consent and then were provided a hard copy of the survey. The research assistant waited nearby as they completed the survey. Upon completion, the participants were debriefed about the purpose of the survey (i.e., provided information about defining water quality and its importance for recreational lake use), asked if they had any questions, and thanked for their time. The data collected in the surveys is available as supplementary materials.

2.4. Materials

The first part of the survey consisted of open-ended questions. In this section, participants provided written responses to the questions in Table 1. Each open-ended question was provided enough space for most participants to write several sentences (the equivalent of three lines on a standard lined sheet of paper).

Table 1. Open-ended survey questions.

Open-Ended Questions
1. How would you define water quality?
2. *How is* this lake being treated by the people and institutions using it?
3. *How should* this lake be treated by the people and institutions using it?
4. Do you have any concerns regarding the water quality of this lake? (Y/N) If so, what are those concerns?

After responding to the open-ended questions, participants were asked to respond to a series of Likert-styled questions. Participants began by responding to the prompt, “How important are the following water quality features to you?” by rating 10 different features on a scale of 1 = “not at all important” to 5 = “Very important.” The water quality features are listed in Table 2. These features were chosen, in part, because they reflected components of the water quality definitions provided by the Nebraska Department of Environment and Energy (see Figure 1). While this list does not explicitly include all possible attributes of a lake that might impact water quality, e.g., micro-organisms or pollution, it does include features of water use that could be impacted by those attributes.

Table 2. Water quality features.

Water Quality Features	
• Water clarity	• Ability to eat fish from the water
• Water color	• Support of a diverse fish population
• Water smell	• The chemical composition of the water
• Ability to swim in the water	• Presence of algae or “green scum” in the water
• Ability to boat in the water	• Presence of plants in the water

Following their ratings of the importance of water quality features, participants responded to a series of additional questions inquiring about their knowledge of actual water quality, familiarity with water quality regulations, and frequency of interactions with the lake site, see Table 3.

Table 3. Knowledge regarding water quality survey questions.

Knowledge Questions
1. How is the water quality at this lake? (1 = very bad; 5 = very good)
2. How has water quality at this lake changed over time? (1 = it has gotten much worse; 5 = it has gotten much better)
3. How familiar are you with the laws and regulations related to water quality for your community lakes and streams? (1 = not at all familiar; 5 = extremely familiar)
4. How familiar are you with the water quality of your community lakes and streams? (1 = not at all familiar; 5 = extremely familiar)
5. How often do you intentionally interact with this lake (e.g., walk or drive by it, swim, fish, boat, etc.)? (1 = never; 7 = more than once a week)

2.5. Coding Participant Generated Definitions of Water Quality

The open-ended questions regarding participants' self-generated definitions of water quality were coded to facilitate quantitative statistical analysis. We used a top-down coding scheme generated by the research team prior to examining the data. The coding scheme involved identifying whether the definitions mentioned each of the ten water quality features identified in Table 2. The coding scheme also included an eleventh feature: the drinkability of the water. The authors decided to add this additional feature based on findings from the literature. The data were coded by two trained undergraduate research assistants. The research assistants completed the coding independently. Then, they discussed any disagreement regarding their independent coding results. In these discussions, the pair determined that the only discrepancies in their individual codes were the result of typographical error. After correcting the typographical errors, the coders were in complete agreement. Thus, inter-rater reliability was 100%.

2.6. Qualitative Analysis—Concerns and Treatment of the Lake

We used thematic analysis techniques to analyze the open-ended questions regarding participants' concerns about water quality and the treatment of the lake (see Table 1, questions 2–4). Thematic analysis involves the identification of themes or concepts in qualitative text data to find patterns of meaning. For each question, the analysis began with the first author reviewing the open-ended responses to become familiar with the data. Next, shorthand codes were assigned to the open-ended responses to describe their content and themes were generated from these codes. Finally, both authors reviewed the themes and collaboratively developed the theme descriptions reported herein.

3. Results

3.1. Participant Demographics

The average age of our participants (n = 82) was nearly 40 years old (Mean = 39.92; Standard Deviation = 17.26). We had approximately even numbers of male and female participants (41 male; 36 female). The vast majority of our participants self-reported their race as "white (Caucasian)" (n = 71). Additional demographic information is reported in the Table A1, Appendix A.

3.2. Biophysical Comparison of Lakes

Biological and chemical parameters analyzed by the Nebraska Department of Energy and Environment are similar between Holmes and Branched Oak Lakes (see Figure A1, Appendix A). In 2019, microcystin concentrations tended to be higher in Branched Oak Lake than Holmes Lake (0.83 ± 0.8 µg L^{-1}, 0.23 ± 0.3 µg L^{-1}, respectively), while *E. coli* concentrations tended to be higher in Holmes Lake than Branched Oak Lake (383 ± 1381 100 mL^{-1}, 52 ± 102 100 mL^{-1}, respectively).

Between 2014 and 2018, nitrogen and chlorophyll *a* concentrations were similar between lakes (nitrogen: Branched Oak: 1.1 ± 0.3 mg N L^{-1}, Holmes Lake: 1.3 ± 0.4 mg N L^{-1}; Chl *a*: Branched Oak: 39 ± 31 μg L^{-1}, Holmes Lake: 43 ± 31 μg L^{-1}), while phosphorus concentrations were higher in Holmes Lake than Branched Oak (164 ± 58 μg P L^{-1} v 93 ± 35 μg P L^{-1}). Hence, the measured biophysical parameters suggest that the lakes were similar in trophic state in 2018 and 2019, the year the surveys were collected.

3.3. Water Quality Features and Definitions

Our first objective was to determine how the public defines water quality when allowed to self-generate a definition. Table 4 reports the number of participants who included the specific feature in their water quality definitions, in the order of the most commonly mentioned feature to least commonly mentioned. Our participants primarily mentioned water clarity, the drinkability of the water, the chemical composition of the water, and the ability to swim in the water.

Table 4. Water quality features discussed in participant-generated definitions of water quality.

Water Quality Feature Discussed	# of Participants	% of Participants
Water clarity	12	14.6
The drinkability of the water	9	11.0
The chemical composition of the water	7	8.5
Ability to swim in the water	6	7.3
Water color	3	3.7
Water smell	3	3.7
Support a diverse fish population	3	3.7
Presence of plants in the water	2	2.4
Presence of algae or "green scum" in the water	1	1.2
Ability to boat in the water	0	0
Ability to eat fish from the water	0	0

We also used this coding scheme to create a complexity score for the participant-generated water quality definitions. For the purpose of this study, we define "complexity" as the number of water quality features included in the definition that reflected components of the water quality definitions provided by the Nebraska Department of Environment and Energy. Including more features (e.g., clarity, color, smell, and fish diversity) suggests that the participant considers a breadth of features when considering water quality. We calculated a complexity score by adding the total number of water quality features discussed in each participant's definitions. The frequency distribution of the number of water quality features mentioned in each definition is reported in Table 5. Over half (54.9%) of the participants did not provide any of the 11 water quality features in the coding scheme in their self-generated definitions of water quality. Of the remaining participants, 35.4% provided only one water quality feature. Only one participant (1.2%) provided a complex definition incorporating three water quality features.

Table 5. Participant-generated definitions of water quality complexity.

# of Water Quality Features Discussed	# of Participants	% of Participants
0	45	54.9
1	29	35.4
2	7	8.5
3	1	1.2

The lack of complexity in self-generated water quality definitions sharply contrasts the average importance ratings for the water quality features. After providing their self-generated definitions, participants rated the importance of water quality features (see Table 6). Overall, the ratings were very high for all the listed features of water quality.

Table 6. Importance of water quality features means (M) and standard deviations (SD).

How Important are the Following Water Quality Features to you?	Holmes		Branched Oak		Total	
	M	SD	M	SD	M	SD
Water clarity	4.45	0.70	3.81	1.13	4.25	0.91
Water color	4.39	0.72	3.87	1.13	4.21	0.90
Water smell	4.71	0.70	4.52	0.59	4.63	0.69
Ability to swim in the water	4.04	1.07	4.89	0.33	4.32	0.97
Ability to boat in the water	3.98	1.09	4.27	1.12	4.01	1.10
Ability to eat fish from the water	3.63	1.44	4.08	1.29	3.80	1.40
Support a diverse fish population	4.12	1.11	4.54	0.81	4.27	1.03
The chemical composition of the water	4.57	0.64	4.77	0.51	4.63	0.61
Presence of algae or "green scum" in the water	4.25	0.93	4.50	0.76	4.33	0.87
Presence of plants in the water	3.92	1.05	4.00	0.85	3.95	0.97
Composite of all features	4.22	0.48	4.32	0.38	4.26	0.45

(scale: 1 = "not at all important" to 5 = "Very important").

3.4. Perceptions of the Water Quality of the Lake

Our second objective was to examine perceptions of water quality and compare those perceptions to actual water quality measures at our lake sites. Participants provided their subjective ratings of the water quality of the lake. An analysis of variance (ANOVA) indicated that participants rated the water quality at Branched Oak Lake as better ($M = 3.56$; $SD = 0.65$) than the water quality at Holmes Lake ($M = 3.05$; $SD = 0.91$), $F(1, 76) = 6.35$, $p = 0.01$, despite similar biological and chemical characteristics between the two lakes. Interestingly, perceptions of water quality were related to familiarity with the laws and regulations related to water quality, $\beta = 0.24$, $t(76) = 2.18$, $p = 0.03$, overall model: $R^2 = 0.06$, $F(1, 76) = 4.73$, $p = 0.03$. The more familiar our participants were with the laws and regulations related to water quality, the more positively they perceived the water quality. There was no relationship between their self-reported familiarity with the water quality or the frequency of their interactions with other bodies of water.

3.5. Qualitative Analysis—Concerns and Treatment of the Lake

Participants also responded to three open-ended questions about their concerns and the treatment of the lake. These questions were qualitatively reviewed by the authors using thematic analysis techniques. The themes that emerged for each question are presented below.

3.5.1. Concerns Regarding the Water Quality of this Lake

Nearly half (46.34%) of our participants listed concerns about the water quality of the lake they were visiting. Examining the responses produced four primary concern themes:

1. Concerns regarding the litter and garbage from other lake-users, as well as pollution from the boats that used the lake;
2. Concerns regarding pollution from water runoff from the city, nearby agriculture, etc.;
3. Concerns about the inability to swim in the lake because of unclean water;
4. Concerns about biological contaminants such as algae blooms, amoebas, etc.

3.5.2. Current Lake Treatment

We also inquired about how our participants thought the lake site was "being treated by the people and institutions using it." The purpose of this question was to better understand lake-users' perceptions of water management practices. Again, four primary themes emerged. In general, participant's responses suggested that they felt the lake was being treated fairly well. They felt that community members and the institutions managing the resource respected the lake. However, concerns were expressed regarding two issues. First, some participants expressed concern that community members could do a better job of not littering and lake managers could supply more trash receptacles (or clean them more frequently). Second, some participants expressed concerns about overfishing and how the lake managers stocked the lake with fish.

3.5.3. Ideal Lake Treatment

The final open-ended response question asked participants about how they thought the lake should "be treated by the people and institutions using it." This allowed participants the chance to offer their perceptions on opportunities for improvement. Five different themes emerged: (1) the lake should be cleaner; (2) people should do more to obey the laws and rules; (3) people should treat the lake with care and respect; (4) there should be less trash and pollution; and (5) there should be more management by the government.

4. Discussion

While governmental policies and regulations define water quality as a multi-faceted term (see Figure 1 as an example), our study suggests that lake-users do not. For the survey, we operationalized "complexity" as the number of water quality features included in the definition. This operationalization was chosen because it did not conflate complexity with the concepts of sophistication or knowledge. This allows for the possibility that the participants could generate a complex definition of water quality without using water science-specific terminology. With our operationalization of complexity, including more features (e.g., clarity, color, smell, and fish diversity) would reflect the multi-faceted definitions seen in governmental policies and regulations. However, the overwhelming majority of participants did not provide more than one feature of water quality in their self-generated definitions that is also found in the relevant policy or regulatory definition. We attempted to rule out methodological reasons that might explain short responses by: (1) providing adequate space for the participant's responses, (2) keeping the survey brief, and (3) asking participants to define water quality as the first question. Thus, we believe the study findings provide some evidence to suggest our participants may not have generated complex definitions because the complexity associated with water quality is not at the forefront of their thoughts. In short, complex definitions do not spontaneously spring to mind. However, there are limitations associated with our survey design and additional research is needed to further explore this possible explanation.

Examining the content of participant's self-generated definitions indicated that water clarity was the most commonly generated component of water quality, similar to previous studies [20,37,38]. The emphasis on visual indicators of water quality was also reflected in participants' open-ended responses to the question regarding their concerns about the water quality. Further, with prompts, lake-users rate highly the importance of many of the properties of water that relate to those definitions of the state and federal government. While our survey was limited in scope to lake-users near Lincoln, Nebraska, these findings suggest a few key insights that warrant further investigation. First, the overwhelming majority of our sample of lake-users did not include more than one feature in their self-generated definition of water quality that reflected the relevant policy or regulatory definition. Further, the self-generated definitions focused primarily on water clarity, a component of water quality that is probably the most self-evident. Further, when provided specific features of water quality to rate, our sample of lake-users rated any provided feature of water quality as highly important. This suggests that the failure to include those features in a self-generated definition is not the consequence of perceiving that feature as low importance.

4.1. Water Quality as Water Clarity?

In both the open-ended question and the rating question about water quality (Tables 4 and 6), "water clarity" came out as a prominent feature of water quality. Water clarity is related to three of the four aspects of water quality defined in the state of Nebraska and in national regulations. Water clarity is related to "biological integrity" as it is related to phytoplankton: as the abundance of phytoplankton, whether algae or cyanobacteria, increases, water clarity tends to decrease. Water clarity is also related to "physical integrity" as it is influenced by sediment loads or turbidity in the water: as sediments or turbidity increase, water clarity decreases. Finally, water clarity can be related to "chemical integrity" in terms of organic matter in the water. Increases in organic matter, particularly chromophoric dissolved organic matter, decrease water transparency, which can decrease water clarity [39].

Yet, while water clarity is related to the biological, chemical, and physical components of water quality in the legal definitions, the relationships among biological, chemical, and physical components of a lake can be complex [40]. In eutrophic conditions like those found in Nebraska, an increase in water clarity may not necessarily be related to an improved status in the lake. For instance, in a limnological study of lakes in Iowa, water clarity was not related to phytoplankton abundance (as defined by chlorophyll *a*) in lakes with high nutrient concentrations (>100 ug P L^{-1} and >500 ug N L^{-1}) [38].

Lakes in Nebraska, like Holmes Lake and Branched Oak Lake, may experience water clarity issues for any of the factors listed above. Yet, the consequences to lake-users and fish and other wildlife of lower water clarity differ based on the influencing factor. If water clarity is low due to high cyanobacterial biomass, that could lead to higher cyanotoxin concentrations and direct impacts on human health (e.g., skin irritation, gastrointestinal issues) or wildlife health (e.g., morbidity) [41,42]. Alternatively, if water clarity is low due to stronger water coloration, this may not have direct impacts for swimming or recreation, but could impact fish habitats via lowered dissolved oxygen concentrations or shifts in temperature profiles [43–45]. Teasing apart these associations is particularly important as recent surveys by the EPA National Lakes Assessment suggest lake "murkiness" or the increase in trophic status (based on total phosphorus) and color (based on true color) is increasing in the temperate and southern plains region of the US, the regions which encompass Nebraska [46].

4.2. Perceptions of Water Quality in Nebraskan Lakes

There are several ways that our results support our hypothesis that perceptions of water quality will be unrelated to lake parameters given the eutrophic and impaired status of these lakes [17,20]. First, despite both Branched Oak and Holmes Lakes being listed as "impaired" on the Section 303(d) list of impaired waters of the US, the majority of lake-users rated these lakes with a water quality index of 4 or greater (58% and 54%, respectively; 4 = "good", 5 = "very good"). Indeed, few people rated water quality low (2 or less) in either lake, although that percentage was greater in Holmes Lake than Branched Oak Lake (22% versus 4%). While lake parameters do change seasonally, and it is possible that visitors were questioned on days when lake parameters were more favorable, we suggest that these answers are not an anomaly as frequency of visitations did not impact lake-user perceptions. It is possible that our sampling procedure was biased toward positive perceptions of water quality because the lake-users had already chosen the location as desirable for recreational use.

Our findings support the argument made by Hull et al. [25] that terms like "quality" in an environmental context are ambiguous and value-laden. Lake-users may be defining lake water quality differently than how it is defined by objective water quality standards [16]. While the Nebraska DEE (Lincoln, NE, USA) considers lake water quality primarily by its use for recreation, aquatic life, agricultural water supply, or aesthetics, an alternative explanation for the higher rating of these lakes than what is suggested by the "impaired" status is that lake-users may rate other aspects of "water quality" more important than those of the Nebraska DEE. However, the ratings from the prompted "water quality" question do not support this interpretation. For example, lake-users rated whether or not the lake could "support a diverse fish population" as an important water quality feature (4.27 ± 1.03), suggesting that the lake-users value aquatic life, one of the components of water quality also considered by the Nebraska DEE.

Interestingly, while fish diversity was rated important, "ability to eat fish from water" was rated lower, 3.8 ± 1.40. This is, perhaps, a good thing as there is a mercury consumption advisory for fish from Holmes Lake [36]. While this result suggests that not all lake-users are visiting the lake for angler purposes, the open response parts of the survey suggest some lake-users are concerned with multiple aspects of the fishery, from stocking practices to overfishing. Furthermore, despite rating the water quality with a 3 or above, the open-ended questions about lake concerns or treatment of the lake suggest lake-users see opportunities for improvement with respect to the state of the lake.

4.3. Familiarity with Laws and Regulations

Our finding that the more familiar a participant was with the laws and regulations regarding water quality, the more positively they perceived water quality was unexpected. The study lakes are deemed "impaired" by the Nebraska DEE, so it seems reasonable to expect that if a lake-user understood the regulations that went into defining the "impaired" status, they would not view the water quality as favorably. This result may reflect the findings of Canter et al. (1992): If the institution managing the environmental issue is trusted, risk is considered lower than if it were not trusted [14]. Hence, if our survey respondents trust the agencies taking care of the lakes, they may be more likely to view the water quality as better, regardless of the impairment status. Better educational efforts on different aspects of water quality may help: when Finnish landowners were educated about different water quality parameters, they rated those parameters more negatively in lakes they lived near [16]. It is also worth noting that although the effect size is small for this effect, even small effect sizes can have a meaningful impact in relation to shifts in human behavior [47,48].

4.4. Study Limitations

As with any study, there are limitations to this research. In particular, this paper presents findings from a pilot data collection effort that involved a relatively small sample of participants from only two lakes in Nebraska. This limits the generalizability of the findings. Further, a review of our participants' demographic features suggests there is a lack of racial and ethnic diversity. Future data collection efforts could enhance the generalizability of the findings by collecting a larger number of participants with an emphasis on attempting to collect a diverse sample. It would also be advantageous to consider data collection at different lakes in a variety of regions. Our data collection focused on lake-user participants, limiting our sample to individuals who had already chosen the lake site for recreational purposes. It would be advantageous to collect a broader sample of participants to also gather information from those who do not go to lakes for recreation. Finally, a review of the water quality definition open-ended question responses indicates that although the majority of our participants responded to the question in some form, many did not end up with a coded feature of water quality because (1) they responded with their perceptions of the water quality at the specific lake site instead of providing a definition or (2) they may have included water quality features that were not listed in our coding scheme (developed prior to examining the data based on the relevant policy and regulatory definitions). Although the question asking for water quality definitions may appear straight forward on its face, participants may have actually been confused by it. This suggests that future studies on this topic might need to consider how best to elicit participants' water quality definitions. Further, it may also be useful to use an expended coding scheme that includes features of water quality that go beyond the relevant policy or regulatory definitions, possibly using an inductive approach to coding the data.

5. Conclusions

Although the sample for the survey was Nebraska-focused and relatively small, the results we found support previous work. The results of our survey suggest the overwhelming majority of our sample of lake-users did not include more than one feature in their self-generated definitions of water quality. The self-generated definitions focused on water clarity, a component of water quality that is one of the most self-evident [20]. Further, when provided specific features of water quality to rate, our sample of lake-users rated any provided feature of water quality as highly important. This suggests that the failure to include those features in a self-generated definition is not the consequence of perceiving that feature as low importance. Rather our participants may not have generated complex definitions because complex definitions do not easily come to mind. Additional research is needed to further explore this possible explanation. This work highlights that the public's definition of water quality does not match the complexity seen in scientific and policy-based definitions (e.g., the water quality definitions provided by the Nebraska Department of Environment and Energy in Figure 1) rendering concern as to lake-users' awareness of compromised water quality or how readily the public would be engaged in management or policy discussions (Hull et al. 2003).

Indeed, one implication of the findings is that outreach or educational efforts to improve water quality may benefit from providing the public, and specifically lake-users, with a more comprehensive definition of water quality to aid in lake use decision-making and promote pro-environmental behavior. Although this study does not directly consider outreach or educational efforts, it does provide additional insight into one issue intervention designers may want to consider. This may be especially important in regions of the world where lake water quality may be compromised by any number of factors (e.g., toxic cyanobacterial blooms, mercury, agrochemicals) including in agriculturally rich regions like Nebraska. Outreach or educational interventions, if effective, may impact water quality by either garnering support for environmental policy change or influencing individual decisions on how to recreate in or near lakes, both of which could have a positive impact on compromised lakes like Holmes Lake and Branched Oak Lake.

Supplementary Materials: The following are available online at https://osf.io/7f3ce/.

Author Contributions: Conceptualization, A.M.V. and J.R.C.; methodology, A.M.V. and J.R.C.; validation, A.M.V. and J.R.C.; formal analysis A.M.V. (survey results) and J.R.C. (lake water quality parameters); investigation, A.M.V. and J.R.C.; resources, A.M.V. and J.R.C.; data curation, A.M.V. and J.R.C.; writing—original draft preparation, A.M.V. and J.R.C.; writing—review and editing, A.M.V. and J.R.C.; visualization, A.M.V. and J.R.C.; supervision, A.M.V. and J.R.C.; project administration, A.M.V. and J.R.C.; funding acquisition, A.M.V. and J.R.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the NEBRASKA RESEARCH INITIATIVE.

Conflicts of Interest: The authors declare no conflict of interest.

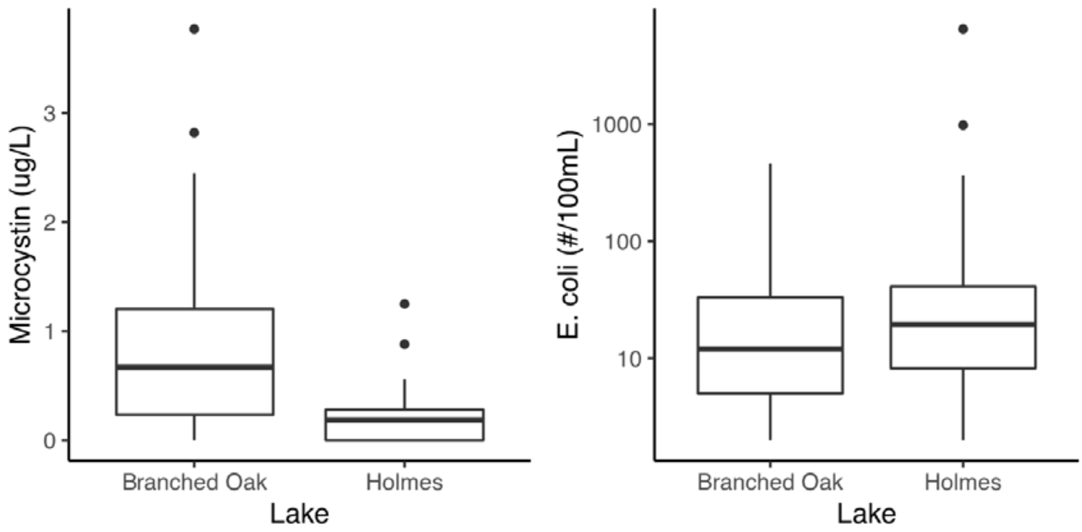
Appendix A

Table A1. Study Participants' Demographic Information.

Variable/Response Option	# of Participants	% of Participants
Gender		
Male	36	43.9
Female	41	50.0
Other	1	1.2
Missing	4	4.9
Are you Hispanic or Latino/a?		
Yes	1	1.2
No	77	93.9
Missing	4	4.9
Race		
White (Caucasian)	71	86.6
Black or African-American	3	3.7
Asian	1	1.2
American Indian or Alaska Native	0	0
Native Hawaiian or other Pacific Islander	0	0
Other	0	0
Missing	5	6.1

Table A1. *Cont.*

Variable/Response Option	# of Participants	% of Participants
Highest level of education		
Less than high school	0	0
High school diploma	15	18.3
Some college or 2-year college degree	19	23.2
4-year college degree	32	39.0
Graduate or professional degree	11	13.4
Missing	5	6.1
Self-reported Social Class		
Upper class	0	0
Upper-middle class	22	26.8
Middle class	45	54.9
Lower-middle class	8	9.8
Working class	2	2.4
Missing	5	6.1
Yearly household income		
Less than $10,000	2	2.4
$10,000 to $19,999	3	3.7
$20,000 to $29,999	3	3.7
$30,000 to $39,999	6	7.3
$40,000 to $49,999	10	12.2
$50,000 to $74,999	14	17.1
$75,000 to $99,999	12	14.6
$100,000 to $199,999	19	23.2
More than $200,000	1	1.2
Missing	12	14.6
Political affiliation		
Democrat	21	25.6
Republican	25	30.5
Independent	24	29.3
Other	4	4.9
Missing	8	9.8
Size of community		
In a rural area (less than 20,000 people)	10	12.2
In a small town (20,000 to 49,999 people)	10	12.2
In a medium-sized city (50,000 to 499,999 people)	45	54.9
In a large city/metropolitan area	11	13.4
In a suburb near a large city	0	0
Missing	6	7.3



(**a**) (**b**)

Figure A1. Water quality parameters, based on (**a**) microcystin concentration and (**b**) *E. coli* counts, in Branched Oak Lake and Holmes Lake during summer 2019. Notice the log scale on (**b**).

References

1. Environmental Protection Agency. National Lakes Assessment 2012: A Collaborative Survey of Lakes in the United States. Available online: https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=OWOW&dirEntryID=328380 (accessed on 8 April 2020).
2. Chapman, D.V. *Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*, 2nd ed.; CRC Press: Cleveland, OH, USA, 1996.
3. Keeler, B.L.; Polasky, S.; Brauman, K.A.; Johnson, K.A.; Finlay, J.C.; O'Neill, A.; Kovacs, K.; Dalzell, B. Linking water quality and well-being for improved assessment and valuation of ecosystem services. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 18619–18624. [CrossRef]
4. Stevens, A.L.; Baird, I.G.; McIntyre, P.B. Differences in Mercury Exposure among Wisconsin Anglers Arising from Fish Consumption Preferences and Advisory Awareness. *Fisheries* **2018**, *43*, 31–41. [CrossRef]
5. Völker, S.; Kistemann, T. The impact of blue space on human health and well-being—Salutogenetic health effects of inland surface waters: A review. *Int. J. Hyg. Environ. Health* **2011**, *214*, 449–460. [CrossRef] [PubMed]
6. Adler, R.W. Coevolution of Law and Science. *Colum. J. Environ. Law* **2019**, *44*, 1–66. [CrossRef]
7. Kaiser, F.G.; Fuhrer, U. Ecological Behavior's Dependency on Different Forms of Knowledge. *Appl. Psychol.* **2003**, *52*, 598–613. [CrossRef]
8. Frick, J.; Kaiser, F.G.; Wilson, M. Environmental knowledge and conservation behavior: Exploring prevalence and structure in a representative sample. *Personal. Individ. Differ.* **2004**, *37*, 1597–1613. [CrossRef]
9. Bamberg, S.; Möser, G. Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *J. Environ. Psychol.* **2007**, *27*, 14–25. [CrossRef]
10. Levine, D.S.; Strube, M.J. Environmental attitudes, knowledge, intentions and behaviors among college students. *J. Soc. Psychol.* **2012**, *152*, 308–326. [CrossRef]
11. Kollmuss, A.; Agyeman, J. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environ. Educ. Res.* **2002**, *8*, 239–260. [CrossRef]
12. Robelia, B.; Murphy, T. What Do People Know about Key Environmental Issues? A Review of Environmental Knowledge Surveys. *Environ. Educ. Res.* **2012**, *18*, 299–321. [CrossRef]
13. Boerschig, S.; Young, R.D. Evaluation of Selected Recycling Curricula: Educating the Green citizen. *J. Environ. Educ.* **1993**, *24*, 17–22. [CrossRef]
14. Canter, L.W.; Nelson, D.I.; Everett, J.W. Public perception of water quality risks: Influencing factors and enhancement opportunities. *J. Environ. Syst.* **1992**, *22*, 163–187. [CrossRef]

15. Steinwender, A.; Gundacker, C.; Wittmann, K.J. Objective versus subjective assessments of environmental quality of standing and running waters in a large city. *Landsc. Urban Plan.* **2008**, *2*, 116–126. [CrossRef]
16. Artell, J.; Ahtiainen, H.; Pouta, E. Subjective vs. objective measures in the valuation of water quality. *J. Environ. Manag.* **2013**, *130*, 288–296. [CrossRef] [PubMed]
17. House, M.; Fordham, M. Public perceptions of river corridors and attitudes towards river works. *Landsc. Res.* **1997**, *22*, 25–44. [CrossRef]
18. Egan, K.J.; Herriges, J.A.; Kling, C.L.; Downing, J.A. Valuing Water Quality as a Function of Water Quality Measures. *Am. J. Agric. Econ.* **2009**, *91*, 106–123. [CrossRef]
19. Cottet, M.; Piégay, H.; Bornette, G. Does human perception of wetland aesthetics and healthiness relate to ecological functioning? *J. Environ. Manag.* **2013**, *128*, 1012–1022. [CrossRef]
20. West, A.O.; Nolan, J.M.; Scott, J.T. Optical water quality and human perceptions: A synthesis. *WIREs Water* **2016**, *3*, 167–180. [CrossRef]
21. Angradi, T.R.; Ringold, P.L.; Hall, K. Water clarity measures as indicators of recreational benefits provided by U.S. lakes: Swimming and aesthetics. *Ecol. Indic.* **2018**, *93*, 1005–1019. [CrossRef]
22. Smeltzer, E.; Heiskary, S.A. Analysis and Applications of Lake User Survey Data. *Lake Reserv. Manag.* **1990**, *6*, 109–118. [CrossRef]
23. Liu, J.; Dietz, T.; Carpenter, S.R.; Alberti, M.; Folke, C.; Moran, E.; Pell, A.N.; Deadman, P.; Kratz, T.; Lubchenco, J.; et al. Complexity of coupled human and natural systems. *Science* **2007**, *317*, 1513–1516. [CrossRef] [PubMed]
24. Cobourn, K.M.; Carey, C.C.; Boyle, K.J.; Duffy, C.; Dugan, H.A.; Farrell, K.J.; Fitchett, L.; Hanson, P.C.; Hart, J.A.; Henson, V.R.; et al. From concept to practice to policy: Modeling coupled natural and human systems in lake catchments. *Ecosphere* **2018**, *9*, e02209. [CrossRef]
25. Hull, R.B.; Richert, D.; Seekamp, E.; Robertson, D.; Buhyoff, G.J. Understandings of environmental quality: Ambiguities and values held by environmental professionals. *Environ. Manag.* **2003**, *31*, 1–13. [CrossRef] [PubMed]
26. Gerson, J.R.; Driscoll, C.T.; Roy, K.M. Patterns of nutrient dynamics in Adirondack lakes recovering from acid deposition. *Ecol. Appl.* **2016**, *26*, 1758–1770. [CrossRef]
27. Momen, D.; Lawrence, G.B.; Nierzwicki-Bauer, J.W.; Sutherland, L.W.; Eichler, J.P.; Harrison, J.P.; Boylen, C.W. Trends in summer chemistry linked to productivity in lakes recovering from acid deposition in the Adirondack region of New York. *Ecosystems* **2006**, *9*, 1306–1317. [CrossRef]
28. Driscoll, C.T.; Driscoll, K.M.; Fakhraei, H.; Civerolo, K. Long-term temporal trends and spatial patterns in the acid-base chemistry of lakes in the Adirondack region of New York in response to decreases in acidic deposition. *Atmos. Environ.* **2016**, *146*, 5–14. [CrossRef]
29. Carpenter, S.R.; Caraco, N.F.; Correll, D.L.; Howarth, R.W.; Sharpley, A.N.; Smith, V.H. Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. *Ecol. Appl.* **1998**, *8*, 559–568. [CrossRef]
30. Seekamp, E.; Mayer, J.E.; Charlebois, P.; Hitzroth, G. Effects of Outreach on the Prevention of Aquatic Invasive Species Spread among Organism-in-Trade Hobbyists. *Environ. Manag.* **2016**, *58*, 797–809. [CrossRef]
31. Teurlincx, S.; Kuiper, J.J.; Hoevenaar, E.C.; Lurling, M.; Brederveld, R.J.; Veraart, A.J.; Janssen, A.B.; Mooij, W.M.; De Senerpont Domis, L.N. Towards restoring urban waters: Understanding the main pressures. *Curr. Opin. Environ. Sustain.* **2019**, *36*, 49–58. [CrossRef]
32. Paul, M.J.; Meyer, J.L. Streams in the Urban Landscape. *Annu. Rev. Ecol. Syst.* **2001**, *32*, 333–365. [CrossRef]
33. Kaushal, S.S.; Likens, G.E.; Pace, M.L.; Haq, S.; Wood, K.L.; Galella, J.G.; Morel, C.; Doody, T.R.; Wessel, B.; Kortelainen, P.; et al. Novel "chemical cocktails" in inland waters are a consequence of the freshwater salinization syndrome. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2018**, *374*. [CrossRef] [PubMed]
34. Kaushal, S.S.; Belt, K.T. The urban watershed continuum: Evolving spatial and temporal dimensions. *Urban Ecosyst.* **2012**, *15*, 409–435. [CrossRef]
35. 2018 Surface Water Quality Integrated Report—(List of Impaired Waters and Water Quality Report). Available online: http://deq.ne.gov/Publica.nsf/Pages/WAT251 (accessed on 3 June 2020).
36. Michl, G. *Regional Ambient Fish Tissue Monitoring Program, 2017 Data Assessment Report*; Nebraska Department of Environmental Quality Water Quality Assessment Section: Lincoln, NE, USA, 2017.
37. Davies-Colley, R.J.; Wilcock, R.J. Here's looking at you—The murky field of water quality. *Soil Water* **1983**, *19*, 29–32.

38. Coughlin, R. The perception and valuation of water quality: A review of research methods and findings. In *Perceiving Environmental Quality: Research and Applications*; Plenum Press: New York, NY, USA, 1976; Volume 9, p. 310.
39. Brezonik, P.L. Effect of Organic Color and Turbidity of Secchi Disk Transparency. *J. Fish. Res. Bd. Can.* **1978**, *35*, 1410–1416. [CrossRef]
40. Brezonik, P.L.; Bouchard, R.W.; Finlay, J.C.; Griffin, C.G.; Olmanson, L.G.; Anderson, J.P.; Arnold, W.A.; Hozalski, R. Color, chlorophyll a, and suspended solids effects on Secchi depth in lakes: Implications for trophic state assessment. *Ecol. Appl.* **2019**, *29*, e01871. [CrossRef]
41. Funari, E.; Testai, E. Human health risk assessment related to cyanotoxins exposure. *Crit. Rev. Toxicol.* **2008**, *38*, 97–125. [CrossRef]
42. Hilborn, E.D.; Beasley, V.R. One Health and Cyanobacteria in Freshwater Systems: Animal Illnesses and Deaths Are Sentinel Events for Human Health Risks. *Toxins (Basel)* **2015**, *7*, 1374–1395. [CrossRef]
43. Finstad, A.G.; Helland, I.P.; Ugedal, O.; Hesthagen, T.; Hessen, D.O. Unimodal response of fish yield to dissolved organic carbon. *Ecol. Lett.* **2014**, *17*, 36–43. [CrossRef]
44. Thrane, J.-E.; Hessen, D.O.; Andersen, T. The Absorption of Light in Lakes: Negative Impact of Dissolved Organic Carbon on Primary Productivity. *Ecosystems* **2014**, *17*, 1040–1052. [CrossRef]
45. Solomon, C.T.; Jones, S.E.; Weidel, B.C.; Buffam, I.; Fork, M.L.; Karlsson, J.; Larsen, S.; Lennon, J.T.; Read, J.S.; Sadro, S.; et al. Ecosystem Consequences of Changing Inputs of Terrestrial Dissolved Organic Matter to Lakes: Current Knowledge and Future Challenges. *Ecosystems* **2015**, *18*, 376–389. [CrossRef]
46. Leech, D.M.; Pollard, A.I.; Labou, S.G.; Hampton, S.E. Fewer blue lakes and more murky lakes across the continental U.S.: Implications for planktonic food webs. *Limnol. Oceanogr.* **2018**, *63*, 2661–2680. [CrossRef] [PubMed]
47. Rosenthal, R. Media violence, antisocial behavior, and the social consequences of small effects. *J. Soc. Issues* **1986**, *42*, 141–154. [CrossRef]
48. Prentice, D.A.; Miller, D.T. When small effects are impressive. *Psychol. Bull.* **1992**, *112*, 160–164. [CrossRef]